Dietary diversity and subsequent mortality in the First National Health and Nutrition Examination Survey Epidemiologic Follow-up Study[1-3]

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ABSTRACT We examined the relation of dietary diversity to subsequent all-cause mortality by using data from the First National Health and Nutrition Examination Survey (NHANES I) Epidemiologic Follow-up Study, 1982–1987. The analytic cohort consisted of 4160 men and 6264 women (including 2556 deaths), 25–74 y at baseline (1971–1975). Twenty-four-hour dietary recalls were evaluated for variety among the five major food groups: dairy, meat, grain, fruit, and vegetable, with a dietary diversity score (DDS); consumption of each food group contributed 1 point to a maximum possible DDS of 5. Age-adjusted risk of mortality was inversely related to DDS ($P \leq 0.0009$) in men and women. The inverse diversity-mortality association was adjusted for potential confounders: education, race, smoking status, and dietary fiber intake; the relative risk of mortality in men and women consuming two or fewer food groups was 1.5 (95% CI 1.2–1.8) and 1.4 (95% CI 1.1–1.9), respectively. In conclusion, diets that omitted several food groups were associated with an increased risk of mortality. *Am J Clin Nutr* 1993;57:434–40.

KEY WORDS Diet and all-cause mortality, dietary diversity, mortality, diet quality and mortality, NHANES I Epidemiologic Follow-up Study, First National Health and Nutrition Examination Survey

Introduction

Several studies have examined the relationship of selected nutrients, food items, and dietary components to all-cause and cause-specific mortality (1–3). Only a few studies to date, however, have used the approach of evaluating the total diet or broad dietary patterns for studying diet and health (4–6). An appraisal of the total diet (distinct from individual nutrients or food items) in relation to health is especially important because typical human diets include combinations of foods and therefore a combination of nutrients.

One approach to assessing the quality of the total diet is to evaluate it for the extent of dietary variety. Because an evaluation of the extent of dietary variety necessitates consideration of all foods consumed in a given dietary measurement period, it provides a measure of quality of the total diet and, not surprisingly, correlates positively with nutritional adequacy (7, 8). Furthermore, since the early 1900s, dietary variety has been a fundamental concept of dietary guidance given to the US public (9–11). Although the goal of early dietary guidance was meeting nutrient requirements, in recent years a number of recommendations intended for reducing the risk of various chronic diseases have also advocated a varied diet (1, 12, 13). Whether consumption of a diet with greater variety confers long-term health advantages, however, has not been examined.

In this report we use a measure of variety among the major food groups to evaluate the total diet and examine its relation to all-cause mortality, by using data from the First National Health and Nutrition Examination Survey (NHANES I) Epidemiologic Follow-up Study (NHEFS).

Methods

NHANES I was conducted from 1971 to 1975 by the National Center on Health Statistics (NCHS) (14). NHEFS was initiated in 1982 by NCHS and other Public Health Service agencies, including the National Institutes of Health (15). The aim of NHEFS is to relate mortality and morbidity at follow-up to nutritional, health, and other information collected in NHANES I (15). Respondents who were 25–74 y of age at the time of initial survey (n = 14 407) were considered eligible for follow-up (15).

Analytic cohort

From the entire NHEFS cohort exclusions were made for lack of baseline 24-h dietary recall (n = 3059), unsatisfactory 24-h recalls based on interviewers' judgement (n = 205), atypical intake because of illness on the day of recall (n = 272), recalls obtained from proxies (n = 334), transcription errors in 24-h recalls (n = 45), and recalls of pregnant and lactating women (n = 125). This resulted in an analytic cohort of 10 424 examinees

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(4160 men and 6264 women) followed from 1971–1975 through 1987, which yielded 2556 deaths because of all causes.

Information on age, income, education, body mass index (BMI), vitamin or mineral supplement use, self-described level of physical activity, blood pressure, and serum cholesterol was obtained at baseline (14). A single 24-h dietary recall was administered to each respondent at baseline by a trained dietary interviewer by using three-dimensional food models to enable estimation of amount of food consumed (14). Estimates of energy and nutrient intake were obtained by using US Department of Agriculture food composition data for the amounts of food reported consumed in each recall (16).

Dietary diversity measure

The measure of dietary diversity, the dietary diversity score (DDS), developed for this analysis, counts the number of food groups: dairy, meat, grain, fruit, and vegetable, consumed daily. The maximum score is 5: 1 point is counted for each group consumed. For example, individuals who report consumption of foods from all five food groups on the day of recall would be given a DDS of 5 whereas those reporting no foods from the fruit and vegetable groups would be given a score of 3. A DDS was calculated for each respondent.

To create the DDS from the 24-h dietary recalls reported, we assigned the 1710 foods reported by adults in NHANES I to one or more of the five broad food groups: dairy, meat, grain, fruit, and vegetable. Foods were grouped based on similarities in nutrient composition and uses in the diet. The dairy group was assigned all milk and milk products. The meat group included both animal and plant protein sources. The grain group included all grain products except cakes, pies, cookies, and pastries. The fruit group included all fresh, canned, frozen, and dried fruits, and fruit juices, but excluded fruit drinks. The vegetable group included all raw, cooked, frozen, and canned vegetables. Food mixtures containing foods from various food groups, for example, mixed dishes with meat, grain, dairy, and vegetables, such as lasagna, were assigned to all the relevant food groups. Respondents consuming only foods excluded from the five groups, such as carbonated and alcoholic beverages, coffee, candy, high-fat snacks, pastries, etc scored zero on the DDS.

To avoid giving credit for consumption of a food group when the amounts reported were small, we also excluded foods consumed in less than a minimum amount. For the meat, fruit, and vegetable groups, the minimum reported amount for inclusion in the diversity score was 30 g for all solid foods with a single ingredient and 60 g for all liquids and mixed dishes. For the dairy and grain groups, this minimum amount was 15 g for all solids and 30 g for all liquids and mixed dishes. The methods used for grouping foods and the rationale for decisions regarding minimum amounts were described previously (17).

Analytical methods

Because of small numbers of study subjects with diversity scores of 0, 1, and 2, the three categories were combined. Crude mortality rates for individuals scoring 0–2, 3, 4, and 5 on the DDS were calculated by dividing the number of deaths in each score category by the total number of person-years contributed by all subjects in that score category. The number of person-years contributed by an individual was calculated from baseline to the date of death or the date of follow-up interview, whichever came first. Age-adjusted death rates, standardized for age distribution of the analytic cohort, were calculated (18). Cox's proportional-hazards regression analysis (19) was used to evaluate the association of DDS, age at initial interview, and other variables to mortality, by using the proportional-hazards general linear model (PHGLM) procedures available in the *SAS* package (20). For test of a linear trend in the association of mortality to diversity, a diversity variable with four values representing diversity scores of 0–2, 3, 4, and 5 was entered into the regression model.

To eliminate the possibility that the observed DDS mortality association was the result of a preclinical disease condition (reverse causation), we evaluated the association of mortality and dietary diversity after exclusion of first 2 (n = 247) or 4 y (n = 531) of follow-up.

Results

The mean age of men and women at baseline in this cohort was 53 and 48 y (range 25–74 y), respectively. Slightly > 36% of men and 26% of women were ≥ 65 years at baseline. The median follow-up period was 14 y.

Table 1 lists the frequency distribution of the DDS in the analytic cohort. Twenty-five percent of all respondents in this cohort scored < 4 on the DDS, with > 5% reporting consumption of two or fewer food groups on the survey day. The proportions of men and women with the various DDSs were roughly similar.

The relation of DDS to other possible risk factors of mortality is shown in **Table 2**. Among the sociodemographic factors, increasing income [reflected in the poverty index ratio (PIR)] and education were associated with high DDS in both men and women. A smaller proportion of women < 50 y of age had scores of 4 and 5 compared with women > 50; among men, however, such a trend was not noted. A higher proportion of whites than nonwhites scored high on the DDS.

In women, low BMI was associated with higher DDS; in men, there was no clear relation of BMI to dietary diversity. A smaller proportion of men and women in the highest tertile of systolic blood pressure had higher DDS relative to those in the lowest and middle tertiles. A higher proportion of current male smokers had low DDS; among women, a higher proportion of those who had never smoked had low DDS. Increasing serum cholesterol was associated with increasing diversity scores in men but not in women. A higher proportion of respondents describing their usual level of physical activity as little reported low DDS.

TABLE 1

Frequency distribution of the dietary diversity score (DDS) in the analytic cohort*

DDS	Total (n = 10,424)	Men (n = 4160)	Women (n = 6264)
		%	
0–2	5.3	4.8	5.6
3	20.3	19.5	20.8
4	39.3	40.2	38.6
5	35.2	35.4	35.0

* DDS counts the number of food groups consumed daily: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.

TABLE 2
The relationship of dietary diversity score to various risk factors of mortality in men and women*

	Men				Women			
	0–2	3	4	5	0–2	3	4	5
	%				%			
Sociodemographic factors								
Age (y)								
<50	4†	20	45	31	6	23	40	30
50–64	5	19	39	36	5	18	38	40
≥65	5	18	36	41	4	18	35	42
Poverty index ratio‡								
<1	11	35	37	17	13	28	38	22
1	0	25	36	39	10	42	37	10
>1	3	17	42	38	4	19	38	38
Education (y)								
<12	8	27	42	24	8	26	39	26
12	2	15	42	41	4	18	39	28
>12	2	13	38	47	2	13	34	50
Race								
Nonwhite	11	32	39	19	10	31	40	19
White	3	17	42	38	4	18	38	39
General risk factors								
Body mass index§								
<22.5	—	—	—	—	4	19	38	40
22.5–26.9	—	—	—	—	5	19	39	36
<23.8	5	19	41	34	—	—	—	—
23.8–26.9	4	19	40	37	—	—	—	—
>26.9	4	20	42	33	8	25	38	29
Systolic blood pressure (mm Hg)								
<120	—	—	—	—	4	16	41	39
120–143	—	—	—	—	5	21	37	37
<126	4	18	40	37	—	—	—	—
126–143	4	18	42	36	—	—	—	—
>143	5	24	39	32	8	22	39	31
Serum cholesterol (mmol/L)								
<5.10	—	—	—	—	6	21	37	36
5.10–6.10	—	—	—	—	6	20	40	34
<5.20	5	21	40	33	—	—	—	—
5.20–6.10	4	20	41	35	—	—	—	—
>6.10	4	18	43	35	5	21	38	35
Smoking status								
Current	6	24	43	28	5	20	39	37
Former	3	16	43	39	4	19	35	43
Never	4	18	36	41	7	24	39	30
Alcohol intake (g/d)								
None	5	20	37	38	6	22	38	33
Low	4	18	40	38	5	19	38	38
High	4	21	44	31	5	20	39	35
Level of physical activity‖								
Little	6	21	38	34	9	23	39	29
Moderate	5	18	40	37	5	21	38	35
A lot	4	20	43	34	5	20	38	37
Dietary risk factors								
Energy intake (kJ/d)								
<4878	—	—	—	—	13	31	35	22
4878–6874	—	—	—	—	3	19	41	37
>6874	—	—	—	—	2	13	38	48
<7079	11	30	36	21	—	—	—	—
7079–10021	3	18	43	36	—	—	—	—
>10021	2	13	41	43	—	—	—	—

	Men				Women			
	0–2	3	4	5	0–2	3	4	5
	%				%			
Energy from fat (%)								
<32	—	—	—	—	7	21	36	37
32–39.7	—	—	—	—	4	20	38	39
<33	6	20	38	36	—	—	—	—
33–40	4	17	41	38	—	—	—	—
>39.7	—	—	—	—	6	22	41	30
>40	4	21	44	31	—	—	—	—
Energy from saturated fat (%)								
<10.8	—	—	—	—	7	23	38	32
10.8–14.5	—	—	—	—	4	20	37	39
<11.4	6	22	39	33	—	—	—	—
11.4–15.1	3	18	42	37	—	—	—	—
>14.5	—	—	—	—	5	20	40	34
>15.1	4	18	43	35	—	—	—	—
Dietary fiber (g/d)								
<5.6	—	—	—	—	12	34	39	15
5.6–9.6	—	—	—	—	2	16	43	39
<7	10	30	36	21	—	—	—	—
7–12	2	17	42	39	—	—	—	—
>9.6	—	—	—	—	2	11	34	52
>12	2	12	36	49	—	—	—	—
Vitamin or mineral supplement use								
None	5	21	41	32	6	23	39	32
Irregular	2	16	46	36	4	18	37	41
Regular	2	12	40	46	3	17	37	43

* Dietary diversity score counts the number of food groups consumed daily: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.

† Each number represents total amount of person-time accumulated by subjects in a risk-factor category (rows) as a percentage of the total amount of person-time accrued by all subjects within that risk-factor category. For example, among all male respondents with <12 y of education, 8% had a DDS of 0–2; however, only 2% of those with ≥12 y of education scored 0–2 on the DDS. All percentages, except those for age, have been age-adjusted by the direct method according to the distribution of the age-specific person-times in the analytic cohort. For body mass index, systolic blood pressure, serum cholesterol, energy intake, percent energy from fat, and dietary fiber; the categories are based on tertile cuts to obtain lower, middle, and upper thirds of distribution.

‡ Poverty index ratio is a ratio of the total household income to income necessary for maintaining a family on a nutritionally adequate food plan at the time of NHANES I. Ratios were calculated by the National Center for Health Statistics and <1.0 is considered below poverty.

‖ Self-described level of usual physical activity.

§ In kg/m^2.

Among the dietary variables, energy intake and dietary fiber intake increased with increasing dietary diversity. There was no clear relation of alcohol or dietary fat intake to DDS. A higher proportion of those in the lowest tertile of saturated fat intake scored ≤ 3 on the DDS relative to the middle and upper tertiles. Regular vitamin or mineral supplement use was associated with higher DDS.

Crude and age-adjusted rates for all-cause mortality according to DDS are presented in **Table 3**. The relative risk of mortality was inversely related to dietary diversity (**Table 4**) in both men and women. A significant linear trend for increasing mortality with decreasing diversity in the diet was observed in both men and women (P for linear trend < 0.00001 in men, ≤ 0.0009 in women) (Table 4).

To examine whether the association of DDS and mortality was confounded by other variables related to mortality and DDS, a series of trivariate regression models composed of the DDS, age, and each one of several potential confounding variables were analyzed. The potential confounders included PIR (< 1, 1, and > 1), education (< 12, 12, > 12 y), race (nonwhite, white), BMI (sex-specific tertiles), blood pressure (sex-specific tertiles), serum cholesterol (sex-specific tertiles), smoking status (never smoked, former smoker, and current smoker), alcohol intake (sex-specific tertiles), level of physical activity (very active, moderately active, and little to none), vitamin or mineral supplement use (do not use, use irregularly, and use regularly), energy intake (sex-specific tertiles), total fat intake (sex-specific tertiles), percent energy from fat (sex-specific tertiles), percent energy from saturated fat (sex-specific tertiles), and dietary fiber intake (sex-specific tertiles). There was slight attenuation of relative risk estimates with inclusion of education, income, smoking status, energy, and dietary fiber in the trivariate models; for other potential confounders the relative risk estimates were unchanged. We included the variables age, education, race, smoking status, and dietary fiber along with the DDS in larger regression models. The relative risk of mortality for those scoring 0–2 relative to 5 on the DDS in the presence of other potential confounders of mortality was 1.5 (95% CI 1.2–1.8) in men and 1.4 (95% CI 1.1–

TABLE 3
Crude and age-adjusted all-cause mortality rates by dietary diversity score (DDS)*

DDS	n	Cases	Crude rate†	Age-adjusted rate
Men				
0–2	201	108	4830	4160
3	812	295	3010	2820
4	1673	535	2570	2510
5	1474	507	2790	2190
Women				
0–2	351	71	1500	1900
3	1303	225	1260	1520
4	2419	399	1220	1410
5	2191	416	1400	1300

* Per 100 000 person-y. DDS counts the number of food groups consumed daily from each of the five groups: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed.

† Crude rates were adjusted for age by the direct method (18), based on the age distribution of the analytic cohort.

1.9) in women (Table 4). The P value for the test of a linear trend in these multivariate models was 0.02 in men and 0.03 in women (Table 4).

Table 5 lists the relative risk estimates associated with DDS after exclusion of cases occurring in the first few years of follow-up. In separate models involving exclusion of both first 2 or 4 y of follow-up, the previously observed inverse relation of mortality to diet diversity was unaltered in both men and women (Table 5). The regression models included the DDS, age, race, education, smoking status, and dietary fiber as independent variables.

We also assessed whether the relation of dietary diversity and mortality was modified because of other risk factors (effect modification). Multivariate regression analysis with indicator variables for each stratum of the risk factor within each category of the DDS was performed for several risk factors. The increased risk of mortality associated with low DDS was present at nearly every level of age, income, education, race, smoking status, and fiber intake; trends suggesting effect modification were not noted (data not shown).

Discussion

In this cohort study based on a national probability sample of the US population, dietary patterns characterized by omission of food groups were associated with an increased risk of all-cause mortality in both men and women. The importance of these findings is underscored by the truism that diet is universally consumed and an elevation in risk because of dietary patterns in 5% of the population translates into a considerable number of exposed individuals (21). After controlling for other major risk factors for mortality, consuming two or fewer food groups relative to five food groups conferred excess risk of 50% in men and 40% in women.

No conclusions regarding specific nutrients or foods are possible from our analysis (it was not our intent). The method used is an approach to evaluate the total diet. The DDS used in this study is a measure of the extent of variety among the major food groups, a measure that has been found to have a strong relationship to dietary quality (8). Not surprisingly, the likelihood of nutritional adequacy is higher in diets that include all the major food groups (7, 8). Individuals scoring < 5 on the DDS omitted several food sources of known essential nutrients from their diets and may therefore have marginal intakes of several nutrients. Habitual intake of diets deficient in several known essential nutrients (and perhaps other less recognized chemical constituents) may be among the underlying biological reasons for the association of diversity and mortality reported here.

It is notable that although < 5% of respondents reported omitting foods from the meat or the grain groups on the survey day, 46% reported no fruit, 25% reported no dairy, and 17% reported no vegetable (data not shown). Among those consuming two or fewer food groups, > 90% did not report fruit, and > 80% omitted foods from the vegetable and dairy groups.

TABLE 4
Relative-risk (RR) estimates and 95% confidence intervals for all-cause mortality by dietary diversity scores (DDS)*

RR estimate	DDS 0–2	DDS 3	DDS 4	DDS 5	χ^2 (P)
Men					
Age-adjusted RR	1.9	1.3	1.2	1.0†	33.3 (0.0000)
95% CI	1.6–2.4	1.1–1.5	1.0–1.3		
Multivariate RR‡	1.5	1.1	1.0	1.0	5.6 (0.02)
95% CI	1.2–1.8	0.9–1.2	0.9–1.2		
Women					
Age-adjusted RR	1.5	1.2	1.1	1.0	10.9 (0.0009)
95% CI	1.2–2.0	1.0–1.4	1.0–1.3		
Multivariate RR	1.4	1.1	1.1	1.0	4.7 (0.03)
95% CI	1.1–1.9	0.9–1.3	0.9–1.2		

* DDS counts the number of food groups consumed daily: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each food group consumed. RR estimates calculated from age-adjusted regression coefficients obtained from the proportional-hazards model (cases = 1445 men; 1111 women).

† Reference category.

‡ Model includes variables for age (y), race, education, smoking status, and dietary fiber intake (g).

TABLE 5
Relative risk (RR) estimates and 95% confidence interval of all-cause mortality associated with dietary diversity score (DDS) after exclusion of first 2 and 4 y of follow-up*

DDS	Year of follow-up	
	All excluding first 2	All excluding first 4
Men		
0–2 RR (95% CI)	1.5 (1.1–1.9)	1.7 (1.3–2.1)
3	1.0 (0.9–1.2)	1.0 (0.9–1.2)
4	1.0 (0.9–1.2)	1.0 (0.9–1.2)
5	1.0†	1.0
χ^2, P	3.9, 0.05	6.6, 0.01
Women		
0–2 RR (95% CI)	1.5 (1.1–2.0)	1.6 (1.2–2.1)
3	1.1 (0.9–1.3)	1.1 (0.9–1.4)
4	1.1 (0.9–1.2)	1.1 (0.9–1.2)
5	1.0	1.0
χ^2, P	5.4, 0.02	6.3, 0.01

* First 2 (cases = 247) and 4 (cases = 531) y of follow-up were excluded to examine whether the DDS mortality association was because of a preclinical condition (reverse causation) at baseline. DDS counts the number of food groups consumed daily from a total of five: dairy, meat, grain, fruit, and vegetable. Maximum score = 5, 1 point is counted for each group consumed. RR estimates were computed from regression coefficients obtained from proportional hazards models that included age (y), race, education, smoking status, and dietary fiber intake (g). All men excluding first 2 y (cases = 1289), excluding first 4 y (cases = 1107); all women excluding first 2 y (cases = 1020), excluding first 4 y (cases = 918).

† Reference category.

Because the DDS is derived from a 24-h dietary intake recall, we wanted to avoid the use of quantitative estimates of nutrient intake or specific food items for classifying individuals in this cohort. Instead we have used the presence or omission of any foods from the broad food groups for classifying respondents. This method may lessen the extent of within-person variance resulting from day-to-day variation in food consumption of free-living individuals, which is a significant source of error in dietary measurement of usual food intake from 24-h dietary recalls (22, 23). For instance, although individuals may not eat fruits and vegetables rich in vitamin A every day, they may be expected to consume some (any) foods from the fruit and vegetable group. Therefore, when using a single dietary measurement, the estimates of usual consumption of any vegetable are likely to be more reliable than estimates of usual consumption of vitamin A–rich vegetables and less likely to lead to misclassification.

Moreover, the likelihood is high that individuals who consume (or do not consume) a vegetable on the recall day, for example, usually consume (or do not consume) vegetables (24). This argument is supported to some extent by our analysis of the Second National Health and Nutrition Examination Survey (NHANES II) 24-h dietary recall data. Not reporting fruits and vegetables on the dietary recall day was consistently associated with low concentrations of serum vitamin C, whereas reporting fruit and vegetable intake was associated with high serum vitamin C concentrations (7). Because serum vitamin C is often used as an index of vitamin C nutritional status (25), the NHANES II results suggest that individuals reporting fruit and vegetable intake on the day of the recall may usually consume these foods.

Quantitative evaluation of food or nutrient intake is dependent on a respondent's estimation of amounts of various foods consumed, another factor known to affect the accuracy of dietary measurement (22). The diversity score developed for this analysis is minimally affected by variations in the amount of foods consumed because consumption beyond a conservative minimum criterion credits the individual with having consumed the food. Nevertheless, the use of 24-h dietary recalls for classifying respondents into categories of usual food-group intake may be expected to result in some misclassification. To our knowledge, estimates of inter- and intraindividual variance ratio for the DDS used here are not available to assess and correct for attenuation in the diversity-mortality relationship.

Neither confounding nor reverse causation were likely explanations for the results observed here. With simultaneous inclusion of several potential confounders in the multivariate models, the independent effect of dietary diversity on mortality was somewhat reduced, but remained significant. Exclusion of first 2 or 4 y of follow-up period did not alter the strength of the diversity-mortality association even after controlling for several potential confounders.

The findings reported have considerable public health implications. Although it is true that recent dietary guidelines recommend (1, 12, 13) the selection of a varied diet, the messages that tend to be stressed are those of reduction in dietary fat and increase in fiber intake. A renewed emphasis on consumption of a varied diet is not inconsistent with achieving the fat and fiber goals and may promote good health without any known detrimental effects. Further investigation of the relation of dietary diversity and other measures of quality of the total diet to health is needed.

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